(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 635 972 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
13.01.1999 Bulletin 1999/02

(51) Int Cl.6: **H04N 1/62**

(21) Application number: 94201902.7

(22) Date of filing: 01.07.1994

(54) **Automated detection and correction of eye color defects due to flash illumination**

Automatische Erkennung und Korrektion von Augenfarbfehlern, die durch Blitzlichtbeleuchtung verursacht wurden

Détection et correction automatique des défauts de couleur de l'oeil à cause d'illumination par flash

(84) Designated Contracting States:
DE FR GB

(30) Priority: **19.07.1993 US 93843**

(43) Date of publication of application:
25.01.1995 Bulletin 1995/04

(73) Proprietor: **EASTMAN KODAK COMPANY**
Rochester, New York 14650-2201 (US)

(72) Inventors:
- **Benati, Paul J., c/o Eastman Kodak Company**
  Rochester, New York 14650-2201 (US)
- **Gray, Robert T., c/o Eastman Kodak Company**
  Rochester, New York 14650-2201 (US)
- **Cosgrove, Patrick A.,**
  c/o Eastman Kodak Company
  Rochester, New York 14650-2201 (US)

(74) Representative: **Buff, Michel et al**
KODAK INDUSTRIE
Département Brevets - CRT
Zone Industrielle - B.P. 21
71102 Chalon sur Saône Cédex (FR)

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EP 0 635 972 B1

Printed by Jouve, 75001 PARIS (FR)

Description

FIELD OF THE INVENTION

The present invention relates to digital detection for eye color defects of a subject in a digital image.

BACKGROUND OF THE INVENTION

In color flash photography a phenomenon know as red eye can occur. The term "red eye" refers to a person's photographically reproduced pupil(s) when they appear red instead of their normal black coloration. [This effect also occurs in flash photography of animals, although the characteristic color may not be red.] The reddish colored light is the result of the light produced by the flash reflecting off the eye's layer immediately behind the retina. To prevent this problem two procedures have been used during image capture: (1) increase the ambient light levels or (2) separate the flash from the camera by several inches. The first solution reduces the size of the pupil thus reducing the quantity of light reflected and also lessens the amount of required flash illumination. The second measure prevents the lens from detecting the reflected light since it is confined to a narrow beam directed back towards its source–the flash. Unfortunately the amateur photographer is not always in a position to execute either of the above solutions. In general the amateur uses a flash to account for the location's lack of ambient light. In addition, many point-and-shoot cameras, as well as some SLR's, have the flash located closely to the lens.

After the image has been digitally captured it is possible to correct the eye color defects. US-A-5,130,789 describes a method by which a region's chroma and luma channels are modified after an operator identifies a region surrounding an eye, and was used as a basis for the preamble of claim 1.

SUMMARY OF THE INVENTION

It is an object of this invention to automatically determine a defective colored eye in an image.

It is another object of this invention to improve the correction by providing separate corrections for body, border, and glint pixels; and also provide for performing correction at different resolutions than that of detection.

These and other objects of the present invention are achieved by the characterizing features of claim 1. Preferred embodiments may be gathered from the dependent claims.

One of the preferred methods of the present invention is an automated method of detecting for eye color defects of a subject in an image due to flash illumination as set forth in claim 1.

The method used by the present invention maintains the '789 patent criterion of recoloration without destroying the region's luma fluctuation. However, the present invention automatically supplies two of the three inputs necessary to perform the disclosure of the '789 patent. Only the general region of interest is required at the beginning of the present invention as opposed to the more precise region requirements of the '789 patent. Also note that the present invention divides each pupil into three pixel categories: (1) body pixels, (2) border pixels, and (3) glint pixels. Each of these pixel types is treated differently in order to create a more natural appearing correction. Furthermore the image resolution from which the region of interest was obtained does not necessarily need to be the resolution at which the present invention corrects.

ADVANTAGES

The present invention is effective to detect eye color defects due to flash illumination and has the advantages of:

(1) minimizing operator intervention,
(2) achieving more accurate eye color defect corrections than was heretofore possible,
(3) allowing for eye color defects to be detected at one image resolution while the correction process takes place in another image resolution, and
(4) sub-dividing the eye color defect pixels into three categories (body, border, and glint) in order to render a more natural appearing eye.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a system in which the present invention is embodied;
Figure 2 illustrates a top level flow diagram of certain aspects of the present invention;
Figure 3 illustrates a detailed flow diagram of the detection phase of Figure 2;
Figure 4 illustrates a detailed flow diagram of the fix phase of Figure 2;

Figure 5 illustrates the hue, lightness, and saturation space which is used in accordance with the present invention;
Figures 6a-6c illustrate the Hue, Lightness, Saturation trapezoidal scoring used in the First Scoring stage 230 of Figure 3 and in the Second Scoring stage 250 shown in Figure 3;
Figure 7 illustrates Area trapezoidal scoring used in the present invention;
Figures 8a and 8b illustrate 45° trapezoidal scoring used in the present invention;
Figure 9 illustrates an example of the scaling up method shown in the Correcting stage 380 shown in Figure 4;
Figure 10 illustrates an example of the scaling down method outlined in the Correcting stage 380 of Figure 4; and
Figure 11 illustrates an example eye color defect whereby each pixel of the eye color defect is deemed as either a: body pixel, border pixel, or glint pixel.

DETAILED DESCRIPTION

Referring to Figure 1, the present invention is implemented using a digitizing scanner 10, a control and logic device 24, such as a computer with a display device 26, and an optical disc writer 36. As shown, a strip of film 15, containing one or more frames 18 of developed film, is placed into a scan gate 12 where the strip of film 15 is scanned under direction of control and logic circuitry 30. As each frame 18 is scanned the resultant image data, represented by block 22, is digitized and transmitted to a memory 28 for storage. The computer 24 process the stored data, in a manner to be described, to provide output image data 32 which may be written to an optical disc 34 by the optical disc writer 36 to provide a report as to the characteristics of the anomalies. The digitized scanner 10 is capable of quantizing pixel values into multiple brightness levels in separate red, green, and blue channels. A minimum number of brightness levels would be approximately 64 for an adequate quality image with a typical number being 256. Although the image data 32 has been described as originating from the operation of scanning film, it is well understood that other well known techniques may be used to provide the image data.

The computer 24 operates the present invention. Referring now to Figure 2, this invention can be broken down into two distinct phases: (1) the detection phase 200 and (2) the fix phase 300. The detection phase 200 can be broken down into five distinct stages (see Figure 3): (1) identification of eye color defect candidate pixels 210, (2) segmentation 220, (3) first scoring 230, (4) region growth (or pixel score transition identification) 240, and (5) second scoring 250. Each stage of the detection phase 200 accesses the results produced by the previous stage creating a data processing chain. The fix phase 300 can be broken down into two sections (see Figure 4): (1) scaling 370 and (2) correcting 380. The resolution section can in turn be broken down into three stages: (1) lower resolution 310, (2) same resolution 320, and (3) higher resolution 330. The correction section can also be broken down into three stages: (1) glint correction 340, (2) body correction 350, and (3) border correction 360.

It is important to note the necessity of this data processing chain. In the case of red eye defects if one were simply to assume that all reddish pixels in an image were defects, then numerous non-red eye pixels would be included with the set of true red eye pixels. Red eye is comprised of both color and spatial cues. To depend on one, but not the other set of cues, will produce incorrect results. It is the building up of clues, produced by each stage in the data processing chain, which allows the present invention to discern between red eye and non-red eye pixels.

What makes red eye so noticeable and distracting to a viewer is the concentration of red elements (e.g., pixels on a CRT) surrounded by non-red elements. An elements' coloration is determined by its combination of the red, green, and blue characterizing values. Therefore, one could conclude that the elements which comprise a red eye region contain more red than green or blue. In fact, experimental results show red eye pixels to observe, on average, a 1.7:1 red to maximum (green, blue) intensity ratio in the video gamma metric. By increasing/decreasing this ratio the invention decreases/increases its sensitivity to red.

By converting an element's RGB values to HLS (hue, lightness, and saturation) space, see Figure 5, one can derive the kind of red observed in flash illuminated human eyes. The following derived values are those used in an existing implementation, but may be adjusted to modify the sensitivity of the present invention:

$$700 \leq \text{Hue} \leq 1010$$

$$40 \leq \text{Luma} \leq 166$$

$$65 \leq \text{Saturation} \leq 256$$

Therefore the ratio and the 3-dimensional HLS region comprise the criteria used in the first stage of the present invention. Any pixel in the given image which adheres to these criteria is represented as a one in a pre-zeroed out bit

map, the color bit map. A bit map is a section of memory which holds ones or zeros. This binary data can represent many things depending on the program which interprets it. In the present invention, the bit maps represent pixels which are eye color defect pixel candidates. Since these maps use only a single bit to represent a piece of data, this data structure can save vast amounts of physical memory. Thus, at the end of this stage only those pixels which pass the above criteria are represented in the color bit map. For a detailed discussion of hue, lightness, and saturation space see Computer Graphics: A Quarterly Report of SIGGRAPH–ACM, Vol. 13, No. 3, Aug. 1979, pp. III - 37 & 38.

Up to this stage the present invention has been working on individual pixels; eliminating those which did not meet the Identification of Eye Color Defect Candidate Pixels stage 210 criteria in Figure 3. It is now time to group these pixels into spatially contiguous groups, termed segments.

The process begins by raster scanning the color bit map until a non-zeroed bit is encountered. This bit is the seed bit. Once found, the seed bit is set to one in the pre-zeroed marked bit map. Next, the segmentor enters a loop which terminates when no bits are "on" in the marked bit map. The first step of the loop is to zero out the current bit in the color bit map. Next, a function is called which searches (in 8-connected fashion) around the current bit in the color bit map for "on" bits. As "on" bits are found, they are placed into the marked bit map if and only if they are not also "on" in the seed bit map. Once all 8-connected "on" bits have been found, the function returns to the segmentor loop. The next step of the loop is to zero out the current bit in the marked bit map and turn "on" the current bit in the seed bit map. Finally, a function is called which searches the marked bit map for the top left non-zeroed bit. This bit now becomes the current bit and the loop cycles again. Eventually the segmentor loop terminates. At this point each segment is validated based on area and shape. Specifically, there are two criteria, eccentricity and number of pixels. The eccentricity of a segment must be greater than a minimum eccentricity and less than a maximum eccentricity, where 0.0 is perfectly round and 1.0 is maximally elongated (i.e., a line). This range of eccentricity values eliminates linear segment types (i.e., pupils are roundish). See Appendix A for the current equations used to implement an eccentricity value. A segment must contain a predetermined minimum and maximum area (in pixels). A segment with fewer than the minimum number of pixels is generally indistinguishable from other image objects (e.g., a patch of skin). If validated, then this segment is entered into the classmap bit map. The zeroing out of the seed bit map ends this part of the segmentor. Before continuing, it is crucial that the reader understand that only two of the four bit maps, the color and classmap bit maps, could currently contain "on" bits. The color bit map might contain "on" bits which belong to other segments, and the classmap bit map can only contain those segments previously found and the current segment.

Lastly, the raster scan of the color bit map continues. When the next non-zeroed bit in the color bit map is encountered it is designated as the seed bit and the process begins anew. This continues until there are no "on" bits in the color bit map.

As a segment is classified, two tasks are performed: (1) insertion of the new segment into the classmap bit map and (2) compilation of data on the segment is accumulated. This data includes eccentricity, a measure of a segment's circular nature; the number of pixels contained within the segment (i.e., area); the segment's score; the best pixel score (i.e., the largest pixel score occurring in the segment); the best pixel's coordinates; and the coordinates of the segment's centroid. Each segment found has its corresponding statistics saved so that the following stages may access them.

<u>Scoring</u>: (see Figure 3)

A continuous-weighting approach to scoring a pixel is taken in the present invention. Various criteria (hue, lightness, saturation, and the ratio test) are taken into consideration and based upon them an eye color defect score is given. Scores range from zero to one, inclusive.

In the present invention a pixel is scored based on its HLS values and whether or not the pixel passes the ratio criterion (i.e., a bi-value score). Each pixel in an image contains a hue, lightness, and saturation value. Given these values a score for each of these channels can be calculated ($score_{hue}$, $score_{lightness}$, and $score_{saturation}$). These scores are produced based on the information presented in Figures 6a-6c. A score for a given channel value equals the corresponding trapezoidal weighting function for that value. Next read the score off the y-axis. For example, if a given pixel has the following HLS values:

H = 73,
L = 75,
S = 68, then the corresponding scores would be:

$score_{hue} = 0.5$
$score_{lightness} = 1.0$
$score_{saturation} = 0.032$.

In pseudo-code, a score is calculated by:

```
if (value_p < value_1) then
    score = 0.0
else if(value_p > value_4) then
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score = 0.0
else if($value_1 \leq value_p < value_2$) then
score = ($value_p$ - $value_1$)/($value_2$ - $value_1$)
else if($value_3$ $value_p \leq < value_4$) then
score = ($value_p$ - $value_4$)/($value_3$ - $value_4$);

where $value_p$ is the channel (hue, lightness, or saturation) of the pixel in question, $value_1$ represents the first point of the trapezoid (h1, l1, or s1), $value_2$ represents the second point (h2, l2, or s2), $value_3$ represents the third point (h3, l3, or s3), and $value_4$ represents the fourth point (h4, l4, or s4). Lastly, these three scores are multiplied together producing a final pixel score ranging from 0.0 to 1.0, inclusive.

The purpose for multiplying individual channel scores together is so that if a pixel fails a channel test (falls outside the trapezoidal region), then that pixel will receive an overall score of zero (i.e., not a eye color defect candidate). Also, a very large score in one channel can partially compensate for low--but acceptable--scores in the other channels.

A segment's score is determined by calculating the average score of the pixels contained within it.

The Region Growth stage 240 is a process for cleaning up segments by eliminating questionable sub-regions which passed the color threshold tests but appear to have unlikely spatial variations.

Digital imaging region growth is a method by which pixels are annexed to a region's already existing pixels. This is analogous to the growth of crystals. For a crystal to begin growing, a piece of dust (or some other material) must exist. Then, as a solution is introduced, some of the dissolved particles precipitate out of solution and begin forming the crystal structure. Growth ends when the particles in the solution drop below a certain concentration. In a similar way, the growth of a digital region begins with a supplied seed pixel and ends when the connected pixels no longer meet the defined criteria of similarity. A segment's seed pixel is obtained during the Segmentation stage 220. This pixel is designated as the coordinates of the best pixel in a given segment.

To start, the Region Growth stage 240 loops through each segment found in the Segmentation stage 220. As described above, each segment contains a best pixel. This pixel is the seed pixel. The method searches (in an 8-connected pattern) around the current pixel and locates all pixels which have scores that are:

$score_{current\ pixel} - 0.5 \leq score_{neighboring\ pixel}$

$score_{neighboring\ pixel} \geq score_{current\ segment}$

Those neighboring pixels which pass one or both of the above two criteria are annexed to the growing region. Only those pixels which were part of the segment, after the Segmentation stage 220, are considered during this stage. This process of annexing pixels continues for each segment until no old segment pixels are left to be verified.

Since the resultant segments from this stage may differ from those of the Segmentation stage 220 (i.e., pixels may have been dropped from the segment's make up), new segment statistics and scores are updated 250.

At this point there is nothing more to do than assume that the segment with the best score is an eye color defect, termed the primary eye (or primary eye segment). If more than one eye is expected in the image window, then an additional search is conducted for other eye color defects, termed secondary eyes (or secondary eye segments). Based on the primary eye segment's area (or number of pixels) and the 45° criteria, a new score is calculated for the other defective eye segment candidates. [The 45° criteria mandates that the secondary eye must be located somewhere within ± 45° of the horizontal, which runs through the centroid of the primary eye (see Figures 8a and 8b). Any segments which are not in this area are given scores of zero (i.e., are not considered to be secondary eye candidates).] The area score ($score_{area}$) is determined based on the triangular weighting function presented in Figure 7. As with the previous scoring methods, the area scores range from 0.0 to 1.0, inclusive. This $score_{area}$ and the $score_{45}$ are multiplied to the score of the segment in question, in order to arrive at the segment's new score. The segment with the top remaining score is assumed to be the secondary eye.

A very important feature of the present invention centers around the fix phase 300 and its flexibility. By this phase the classmap bit map should contain the eye color defects within the image. Now, the invention must replace each eye color defect with a natural appearing pupil. To accomplish this rendering two important issues must be investigated: (1) scaling 370, and (2) correcting 380.

<u>Scaling</u>: (see Figure 4, 370).

The flexibility alluded to above involves the interdependencies of the detection phase 200 with the fix phase 300. One might wish to perform the detection phase 200 in some image resolution, but perform the fix phase 300 in another. To account for this flexibility, the Scaling section 370, in Figure 4, is subdivided into three sections: (1) fixing at the same resolution 320 as detection, (2) fixing at a higher resolution 330, and (3) fixing at a lower resolution 310. Each of these sections is handled differently. To fix at the same resolution 320 requires no added classmap bit map handling. All that is needed is to correct each pixel which is represented in the classmap bit map (see Correcting below). To fix at higher or lower resolutions requires the creation of a new bit map, the scaledClassMap.

The problem when correcting at a higher resolution 330, is that each pixel in the classmap actually has contributions

from several pixels at the higher resolution. Some of these pixels may be eye color defect pixels, but others may not. Thus, a refined eye color defect selection process must be performed at the higher resolution.

The process of fixing an image at a higher resolution entails the formation of a scaled up version of the classmap bit map. The first step of the process is to pass the scaled version of the original image (the image which the detection phase 200 worked on) to the Identification of Eye Color Defect Candidate Pixels stage 210. This stage returns a scaledColor bit map. Next, each segment contained within the classmap bit map is examined. As each segment is encountered its best pixel's coordinates are scaled up by the appropriate x-/y-scale factors. In theory these coordinates will be at most ± the x-/y-scale factor number of coordinates away from the original coordinates multiplied by their scale factor value, respectively. For example, if an image contained one eye color defect and the present invention correctly detected it, then the classmap bit map shown in the upper left-hand corner of Figure 9 would be the result. Furthermore, if the user requested that the fix phase 300 be performed on the image scaled by 2 (in both the x and y directions), then the scaledColor bit map shown in the lower-right corner of Figure 9 would be the result. Figure 9 depicts the bit located at (4, 2) in the classmap has been designated as the best pixel (see Segmentation 220). When these coordinates are multiplied by the respective scale factors (two for both coordinates in this example), the resulting bit is located at (8, 4)--designated in Figure 9 by a 'X'. Unfortunately this bit location is not classified as a eye color defect candidate in the scaledColor bit map. Therefore, a search is undertaken to find the closest eye color defect candidate in the scaledColor bit map. Once found, this location is used as the seed point for the Segmentation stage 220. Finally the Region Growth stage 240 is invoked and a valid class map bit map, the scaledClassMap, is produced. All that is left now is to correct the pixels in the scaled version of the original image which are categorized as eye color defect pixels in the scaledClassMap bit map (see Correction below). The above outlined methodology does not simply scale up the classmap bit map. If one were to replace every bit in the lower resolution with N (where N equals x-scale factor time y-scale factor) number of bits, then the resulting class map, the scaledClassMap, would over-estimate the true number of pixels contained within the eye color defect.

A correction at a lower resolution 310 is opposite to a correction in a higher resolution 330 (i.e., each pixel in the lower resolution image contains information based on multiple pixels from the detect phase 200 image). Some of these detect phase 200 image pixels may be classified as eye color defect pixels while others may be classified as non-eye color defect pixels. The correction process here is substantially simpler than for up-scaling since no region growth refinement is needed to produce a more accurate class map.

For every NxM (where N equals the x-scale factor and M equals the y-scale factor) grouping of pixels in the original detection phase 190 image, there corresponds a single lower resolution pixel. Since each pixel in the NxM pixel grouping is not guaranteed to be a eye color defect pixel, the corresponding lower resolution pixel may not possess the necessary characteristics to be termed a eye color defect candidate pixel by the detection phase 200. This is a problem. For a program to correct only the parts of a lower resolution pixel which are derived from true eye color defect candidates of the original resolution image, correct each lower resolution pixel by a percentage of the full correction. This percentage can be derived by knowing the number of eye color defect candidates contained within each NxM grouping of original image pixels. Figure 10 shows a classmap bit map and its corresponding scaledClassMap bit map. Again, to simply scale each bit in the classmap by the corresponding x-/y-scale factors to arrive at the scaledClassMap would over-estimate the number of pixels contained within an eye color defect. Furthermore, these pixels would be over corrected.

Correcting: (see Figure 4, 380).

Pupils which exhibit the red eye phenomenon differ from normal pupils in that they are reddish in hue (rather than neutral), and are brighter. Correction is generally accomplished by removing a pixel's chromaticity and darkening its luminance. To perform this task, a given pixel's gamma RGB values are converted to YCC values. [YCC space is a simple translation of RGB space. To transform an image in RGB space to YCC space, multiply each pixel by the following matrix:

$$[R\,G\,B]\times\begin{bmatrix}0.229 & 0.587 & 0.114\\ 0.701 & -0.587 & -0.114\\ -0.229 & -0.587 & 0.886\end{bmatrix}=\begin{bmatrix}Y\\ C_1\\ C_2\end{bmatrix}$$

where R, G, and B represent the gamma-metric red, green, and blue coordinates of a given pixel, and Y, C1, and C2, represent the luminance, chroma-channel 1, and chroma-channel 2 coordinates of the pixel in YCC space. The gamma RGB and the YCC color metrics are described in the KODAK PhotoCD Products: A Planning Guide for Developers,

Eastman Kodak Company, 1992 (part no. DCI200R).] Next, both chroma channels are zeroed out (i.e., only the pixel's neutral value is left). At this point, the luminance channel is multiplied by a factor of 0.35 in order to reduce the lightness of the pixel's neutral value. (In general, a red eye has an unusually high luminance value due to the over abundance of light produced by the flash of the camera which illuminates the retina. Thus, upon correction, a reduction of this high luminance value is required. This factor, 0.35, is based upon experimental evidence and other values may result in natural renderings.) Finally, the YCC values are converted back to gamma RGB values, and set as the pixel's values. The above procedure describes Body correction 350. This is the method by which body pixels--pixels which are 8-connected only to eye color defect pixels--are desaturated (see Figure 11). Border correction 360 is performed on border pixels, pixels which are 8-connected to at least one non-eye color defect pixel and to at least one eye color defect pixel. Such pixels are only darkened by a 0.15 factor. Furthermore, those pixels which are considered to be associated with the glints of a eye color defect are sometimes found to contain subtle red hues. Those pixels which: (1) are not eye color defect pixels, (2) are within 40% of the pupil's calculated radius from the pupil's centroid, and (3) have hue values which range from 600 and 1100, inclusive, are termed glint pixels. To perform Glint correction 340, the chroma channels of glint pixels are zeroed out, while their luminance is left unchanged.

This invention has been described with reference to correcting "red eye" defects, but those skilled in the art will recognize that it is also applicable for correcting for eye color defects in animals, but that different detection and correction values specific to the subject's defective color should be used. Moreover, although two specific color spaces have been used, others will suggest themselves to those skilled in the art.

PARTS LIST

10 digitized scanner
12 scan gate
15 film
18 frames
22 block
24 control & logic device (computer)
26 display device
28 memory
30 logic circuitry
32 image data
34 optical disc
36 disc writer
200 detection phase
210 defect candidate pixels
220 segementation stage
230 first scoring stage
240 region growth stage
250 second scoring
300 fix phase
310 lower resolution
320 same resolution
330 higher resolution
340 glint correction
350 body correction
360 border correction
370 scaling logic
380 correcting logic

Claims

1. An automated method of detecting for eye color defects of a subject in a digital image due to flash illumination, including

   defining (100) a spatial region within the digital image in which one or more eye color defects may exist, which region includes at least a portion of the subject's head;
   sampling pixels within such spatial region for their color content and comparing each such sampled pixel with

a plurality of threshold values which are representative of eye color defects to identify possible eye color defect pixels (210); and
segmenting (220) the identified possible eye color defect pixels into one or more spatially contiguous groups; characterized by:
a) calculating (230) a first score for each pixel of each segmented group and for each group based upon a plurality of features including group size, group shape, coloration, and brightness to identify eye color defect group candidates;
b) selecting a seed pixel based on its score from each identified eye color defect group candidate and determining all the neighboring pixels which are within a predetermined score range of their neighboring pixels and those pixels in a group which represent a significant pixel score transition so that the determined transitions identify the outer boundary of an eye color defect group candidate (240);
c) calculating (250) a second score for each pixel for each eye color defect group candidate based on a plurality of features including group size, group shape, coloration, and brightness;
d) selecting the best group score of an eye color defect group candidate and comparing it relative to a predetermined threshold group score to determine whether a first eye color defect group is present and identifying it as corresponding to the most likely eye; and
e) determining whether a second actual eye color defect group is present based on whether the area of one of the color defect candidate's eye is within a predetermined threshold ratio of the area of the first actual eye color defect group corresponding to the most likely eye, and whether this group candidate is within a predetermined threshold angular subtense of the most likely eye along the predetermined horizontal axis of the subject's head.

2. The method of claim 1 wherein the group size feature is area, the group shape feature is eccentricity, the coloration and brightness features are hue, saturation, lightness, and red to maximum (green, blue) ratio.

3. The method of claim 1 or 2 wherein the scores per pixel in steps a) and c) are equal to the product of the scores of individual features, and the scores of individual features are weighted functions of the feature values of the pixels.

4. An automated method of detecting and correcting for eye color defects of a subject in a digital image due to flash illumination, including the method of any of the preceding claims and further comprising the steps of:
f) correcting (300) the defective color in each eye color defect group by:

(i) determining (370) the correct resolution and whether each pixel at the corrected resolution is an eye color defect pixel;
(ii) categorizing (380) the eye color defect pixels at the corrected resolution into either body, border, or glint categories; and
(iii) correcting (340,350,360) the eye color defect pixels in the body, border, or glint categories.

5. The method of claim 4 wherein the threshold value represents minimum and maximum allowed values consistent with the expected color of a eye color defect group.

6. The method of any of the preceding claims wherein the group score is an average of all the pixels.

7. The method of claim 4 wherein step f) (i) includes determining at a lower resolution a correction factor for each low resolution pixel which is a function of the number of eye color defect pixels at the original resolution disposed at the same image location.

8. The method of claim 4 wherein step f) (i) includes categorizing at a higher resolution each original eye color defect pixel into eye color defect pixels and non-eye color defect pixels.

9. The method of claim 4 including desaturating and reducing the illuminance for each body, border, and glint pixel.

Patentansprüche

1. Automatisiertes Verfahren zum Erkennen von Augenfarbfehlern einer Person in einem Digitalbild, die durch Blitzlicht verursacht wurden, mit folgenden Schritten:

- Definieren (100) eines räumlichen Bereichs innerhalb des Digitalbildes, in dem eventuell ein oder mehrere Augenfarbfehler vorhanden sind und der zumindest einen Teil des Kopfes der Person aufweist;
- Abtasten von Pixeln in diesem Bereich auf ihren Farbanteil und Vergleichen jedes der abgetasteten Pixel mit einer Vielzahl von Augenfarbfehler kennzeichnenden Schwellenwerten, um mögliche Augenfarbfehler-Pixel (210) zu identifizieren; und
- Segmentieren (220) der identifizierten möglichen Augenfarbfehler-Pixel in eine oder mehrere räumlich zusammenhängende Gruppen;

gekennzeichnet durch

a) Berechnen (230) eines ersten Werts für jedes Pixel jeder Gruppe und für jede Gruppe auf der Grundlage einer Vielzahl von Merkmalen, die Gruppengröße, Gruppenform, Färbung und Helligkeit umfassen, um Kandidaten für Augenfarbfehlergruppen zu identifizieren;
b) Auswählen eines Startpixels auf der Grundlage seiner Bewertung von jedem identifizierten Kandidaten der Augenfarbfehlergruppen und Bestimmen aller benachbarten Pixel, die innerhalb eines vorgegebenen Bewertungsbereichs ihrer benachbarten Pixel liegen, und jener Pixel in einer Gruppe, die einen deutlichen Pixelwertübergang darstellen, so daß die bestimmten Übergänge die äußere Grenze eines Kandidaten (240) der Augenfarbfehlergruppen identifizieren;
c) Berechnen (250) eines zweiten Werts für jedes Pixel eines jeden Kandidaten der Augenfarbfehlergruppen auf der Grundlage einer Vielzahl von Merkmalen, die Gruppengröße, Gruppenform, Färbung und Helligkeit umfassen;
d) Auswählen der besten Gruppenwertung eines Kandidaten der Augenfarbfehlergruppen und Vergleichen dieses Werts mit einem vorgegebenen Gruppenschwellwert, um festzustellen, ob eine erste Augenfarbfehlergruppe vorhanden ist, und Identifizieren dieser Gruppe als eine, die mit hoher Wahrscheinlichkeit ein Auge darstellt; und
e) Feststellen, ob eine zweite tatsächliche Augenfarbfehlergruppe vorhanden ist, darauf basierend, ob der Bereich eines der Augen des Farbfehlerkandidaten innerhalb eines vorgegebenen Grenzwertes des Bereichs der ersten tatsächlichen Augenfarbfehlergruppe, die mit hoher Wahrscheinlichkeit ein Auge darstellt, und ob dieser Gruppenkandidat innerhalb eines vorgegebenen Grenzwinkels des wahrscheinlichen Auges entlang der vorgegebenen horizontalen Achse des Kopfes der Person liegt.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß das Merkmal der Gruppengröße Fläche, das der Gruppenform Exzentrizität, das der Färbung und Helligkeit Farbton, Sättigung, Helligkeit und das Verhältnis Rot zu Maximum (Grün, Blau) bedeutet.

3. Verfahren nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß die Werte pro Pixel in Schritt a) und c) gleich dem Produkt der Werte der einzelnen Merkmale, und die Werte der einzelnen Merkmale gewichtete Funktionen der Merkmalswerte der Pixel sind.

4. Automatisiertes Verfahren zum Erkennen und Korrigieren von Augenfarbfehlern einer Person in einem Digitalbild, die durch Blitzlicht verursacht wurden, nach dem Verfahren eines der vorhergehenden Ansprüche mit folgenden zusätzlichen Schritten:
f) Korrigieren (300) des Farbfehlers in jeder Augenfarbfehlergruppe durch:

(i) Bestimmen (370) der richtigen Auflösung und Feststellen, ob jedes Pixel bei der korrigierten Auflösung ein Augenfarbfehlerpixel ist;
(ii) Einteilen (380) der Augenfarbfehlerpixel bei korrigierter Auflösung in entweder Körper-, Grenz- oder Blitzreflexionsbereiche; und
(iii) Korrigieren (340, 350, 360) der Augenfarbfehlerpixel im Körper-, Grenz- oder Blitzreflexionsbereich.

5. Verfahren nach Anspruch 4, dadurch gekennzeichnet, daß der Schwellenwert zulässige Mindest- und Höchstwerte darstellt, die der erwarteten Farbe einer Augenfarbfehlergruppe entsprechen.

6. Verfahren nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß der Gruppenwert ein Durchschnittswert aller Pixel ist.

7. Verfahren nach Anspruch 4, dadurch gekennzeichnet, daß Schritt f) (i) das Bestimmen, bei niedrigerer Auflösung, eines Korrekturfaktors für jedes Pixel mit niedriger Auflösung einschließt, der eine Funktion der Anzahl der Au-

genfarbfehlerpixel bei der ursprünglichen Auflösung ist, die an der gleichen Bildstelle vorhanden sind.

8. Verfahren nach Anspruch 4, dadurch gekennzeichnet, daß Schritt f) (i) das Einteilen, bei höherer Auflösung, jedes ursprünglichen Augenfarbfehlerpixels in Augenfarbfehlerpixel und Nicht-Augenfarbenfehlerpixel einschließt.

9. Verfahren nach Anspruch 4, gekennzeichnet durch Desaturieren und Reduzieren der Beleuchtungsstärke für jedes Körper-, Grenz- und Blitzreflexionspixel.

Revendications

1. Procédé automatisé de détection des défauts de couleur d'oeil d'un sujet dans une image numérique dus à un éclairage au flash, comprenant

   la définition (100) d'une région spatiale à l'intérieur de l'image numérique dans laquelle un ou plusieurs défauts de couleur d'oeil peuvent exister, laquelle région comprend au moins une partie de la tête du sujet,
   l'échantillonnage des pixels à l'intérieur d'une telle région spatiale quant à leur teneur en couleur et la comparaison de chaque tel pixel échantillonné à une pluralité de valeurs de seuil qui sont représentatives de défauts de couleur d'oeil afin d'identifier des pixels de défauts de couleur d'oeil possibles (210), et
   la segmentation (220) des pixels de défauts de couleur d'oeil possibles identifiés en un ou plusieurs groupes spatialement contigus, caractérisé par

   a) le calcul (230) d'une première évaluation pour chaque pixel de chaque groupe segmenté et pour chaque groupe sur la base d'une pluralité de caractéristiques comprenant la dimension du groupe, la forme du groupe, la coloration et la luminosité afin d'identifier des candidats de groupes de défauts de couleur d'oeil,
   b) la sélection d'un pixel germe sur la base de son évaluation à partir de chaque candidat de groupe de défauts de couleur d'oeil identifié et la détermination de tous les pixels voisins qui se trouvent à l'intérieur d'une plage d'évaluation prédéterminée de leurs pixels voisins et de ceux des pixels dans un groupe qui représentent une transition d'évaluation de pixels significative, de sorte que les transitions déterminées identifient la limite externe d'un candidat de groupe de défauts de couleur d'oeil (240),
   c) le calcul (250) d'une seconde évaluation pour chaque pixel de chaque candidat de groupe de défauts de couleur d'oeil sur la base d'une pluralité de caractéristiques comprenant la dimension du groupe, la forme du groupe, la coloration et la luminosité,
   d) la sélection de la meilleure évaluation de groupe d'un candidat de groupe de défauts de couleur d'oeil et la comparaison de celle-ci à une évaluation de groupe de seuil prédéterminée afin de déterminer si un premier groupe de défauts de couleur d'oeil est présent, et l'identification de celui-ci comme correspondant à l'oeil le plus probable, et
   e) la détermination de ce qu'un second groupe de défauts de couleur d'oeil réel est présent sur la base de ce que l'aire de l'un des candidats de défaut de couleur d'oeil est à l'intérieur d'un rapport de seuil prédéterminé de l'aire du premier groupe de défauts de couleur d'oeil réel correspondant à l'oeil le plus probable, et de ce que ce candidat de groupe est à l'intérieur d'un angle sous-tendu de seuil prédéterminé de l'oeil le plus probable suivant l'axe horizontal prédéterminé de la tête du sujet.

2. Procédé selon la revendication 1, dans lequel la caractéristique de dimension du groupe est l'aire, la caractéristique de forme du groupe est l'excentricité, les caractéristiques de coloration et de luminosité sont la teinte, la saturation, la luminance, et le rapport du rouge au maximum (vert, bleu).

3. Procédé selon la revendication 1 ou 2, dans lequel les évaluations par pixel des étapes a) et c) sont égales au produit des évaluations des caractéristiques individuelles, et les évaluations des caractéristiques individuelles sont des fonctions pondérées des valeurs des caractéristiques des pixels.

4. Procédé automatisé de détection et de correction des défauts de couleur d'oeil d'un sujet dans une image numérique dus à un éclairage au flash, comprenant le procédé selon l'une quelconque des revendications précédentes, et comprenant en outre les étapes :

   f) corriger (300) la couleur défectueuse dans chaque groupe de défauts de couleur d'oeil en :

   (i) déterminant (370) la résolution correcte et si chaque pixel à la résolution corrigée est un pixel de défaut de couleur d'oeil,

(ii) catégorisant (360) les pixels de défaut de couleur d'oeil à la résolution corrigée en catégories soit de corps, soit de bordure, soit de reflet, et
(iii) corrigeant (340, 350, 360) les pixels de défaut de couleur d'oeil dans les catégories de corps, de bordure ou de reflet.

5. Procédé selon la revendication 4, dans lequel la valeur de seuil représente des valeurs minimum et maximum permises cohérentes avec la couleur prévisible d'un groupe de défauts de couleur d'oeil.

6. Procédé selon l'une quelconque des revendications précédentes, dans lequel l'évaluation de groupe est une moyenne de tous les pixels.

7. Procédé selon la revendication 4, dans lequel l'étape f) (i) comprend la détermination à une résolution inférieure d'un facteur de correction pour chaque pixel à basse résolution qui est une fonction du nombre des pixels de défaut de couleur d'oeil à la résolution d'origine disposés au même emplacement de l'image.

8. Procédé selon la revendication 4, dans lequel l'étape f) (i) comprend la catégorisation à une résolution supérieure de chaque pixel de défaut de couleur d'oeil d'origine en des pixels de défaut de couleur d'oeil et des pixels qui ne sont pas des défauts de couleur d'oeil.

9. Procédé selon la revendication 4, comprenant la désaturation et la réduction de la luminance pour chaque pixel de corps, de bordure et de reflet.

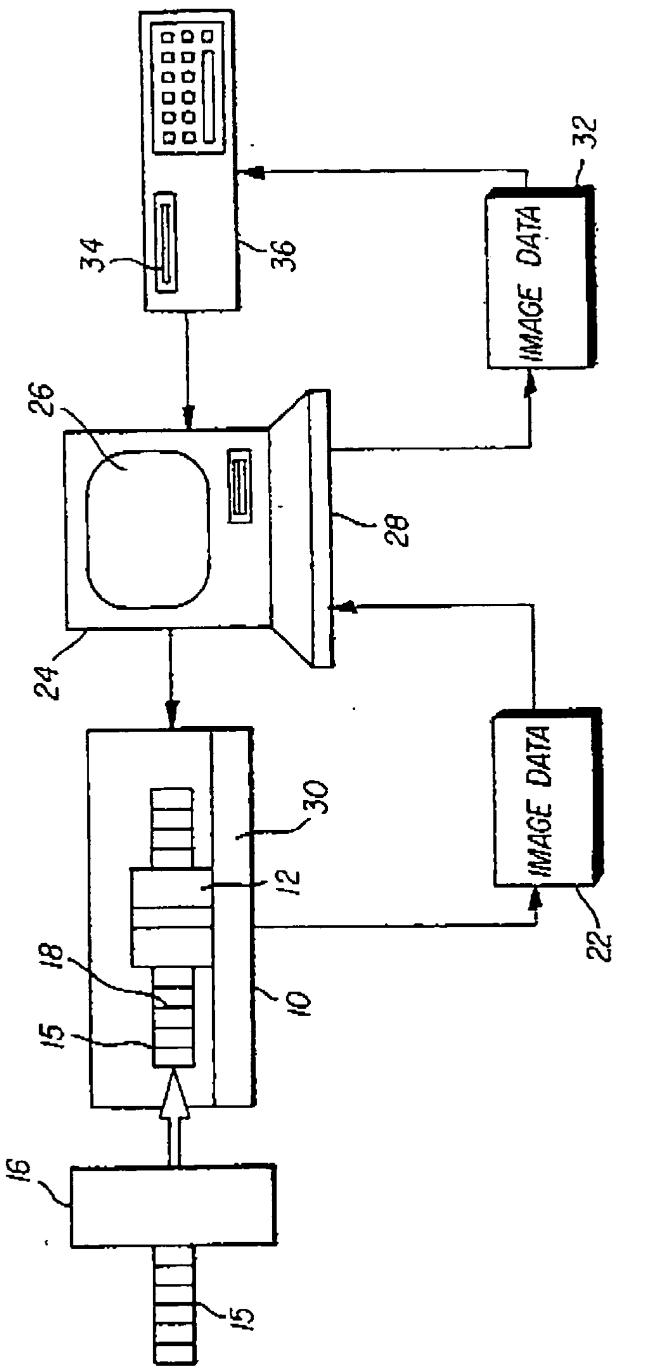


FIG. 1

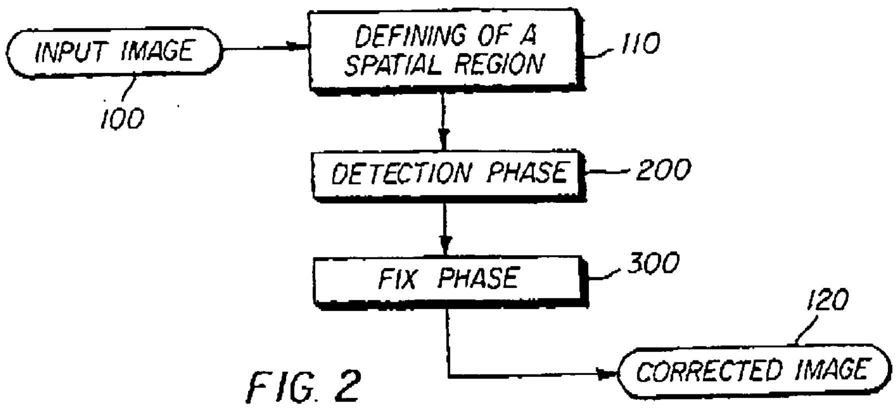

INPUT IMAGE
100
DEFINING OF A SPATIAL REGION
110
DETECTION PHASE
200
FIX PHASE
300
120
CORRECTED IMAGE

FIG. 2

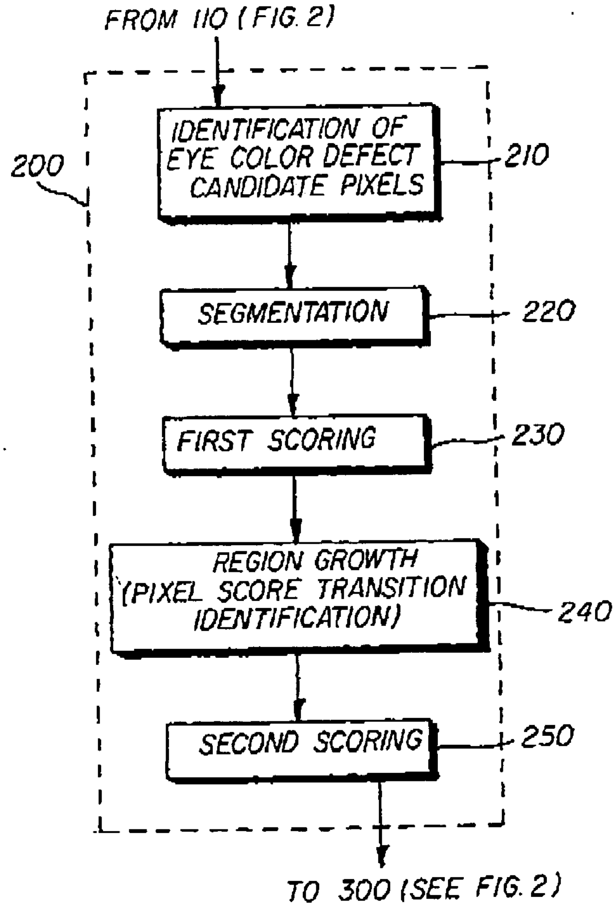

FROM 110 (FIG. 2)
200
IDENTIFICATION OF EYE COLOR DEFECT CANDIDATE PIXELS
210
SEGMENTATION
220
FIRST SCORING
230
REGION GROWTH (PIXEL SCORE TRANSITION IDENTIFICATION)
240
SECOND SCORING
250
TO 300 (SEE FIG. 2)

FIG. 3

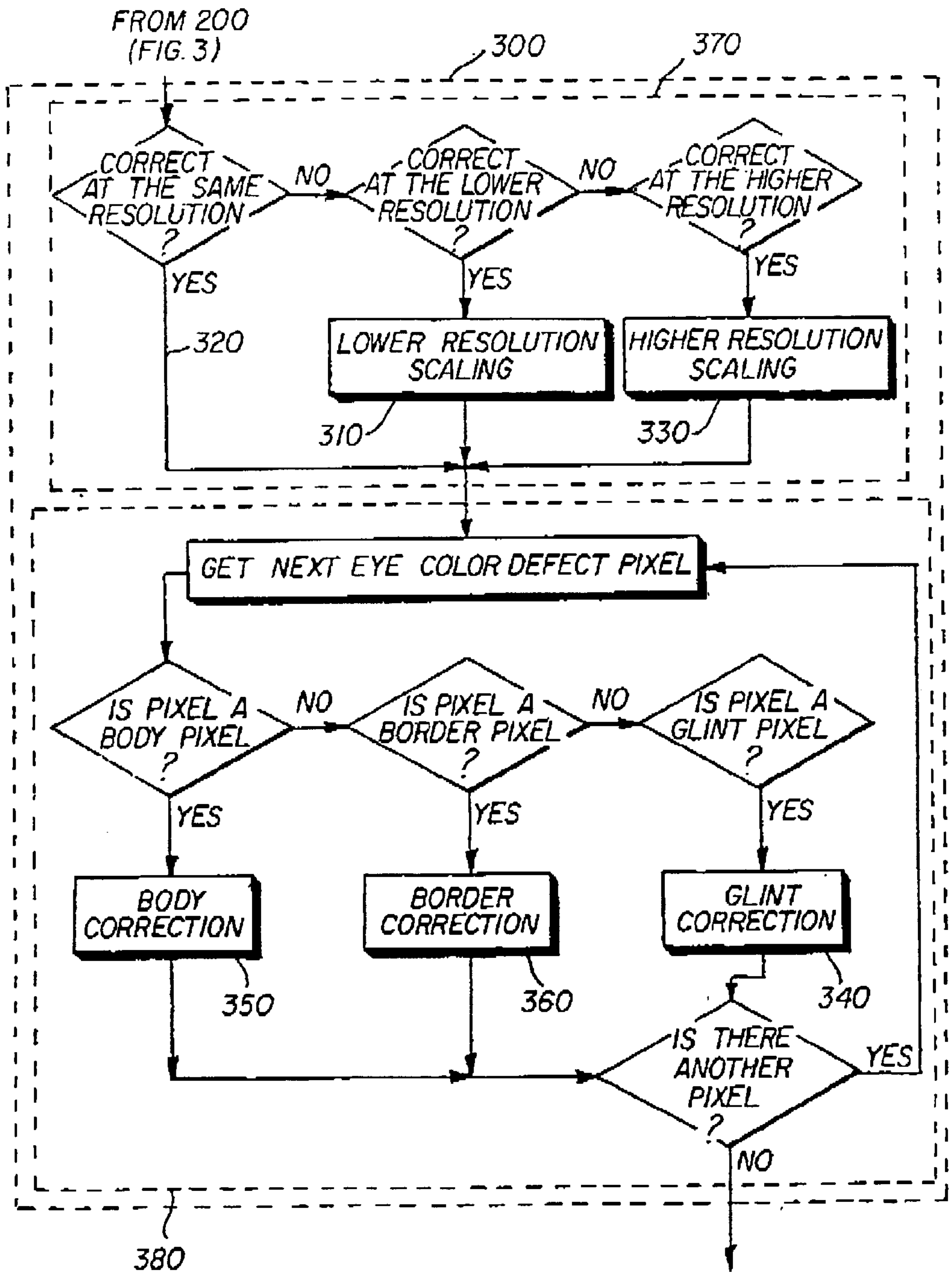

FROM 200 (FIG. 3)
300
370
CORRECT AT THE SAME RESOLUTION ?
NO
CORRECT AT THE LOWER RESOLUTION ?
NO
CORRECT AT THE HIGHER RESOLUTION ?
YES
YES
YES
320
LOWER RESOLUTION SCALING
HIGHER RESOLUTION SCALING
310
330
GET NEXT EYE COLOR DEFECT PIXEL
IS PIXEL A BODY PIXEL ?
NO
IS PIXEL A BORDER PIXEL ?
NO
IS PIXEL A GLINT PIXEL ?
YES
YES
YES
BODY CORRECTION
BORDER CORRECTION
GLINT CORRECTION
350
360
340
IS THERE ANOTHER PIXEL ?
YES
NO
380
TO 120 (FIG. 2)

FIG. 4

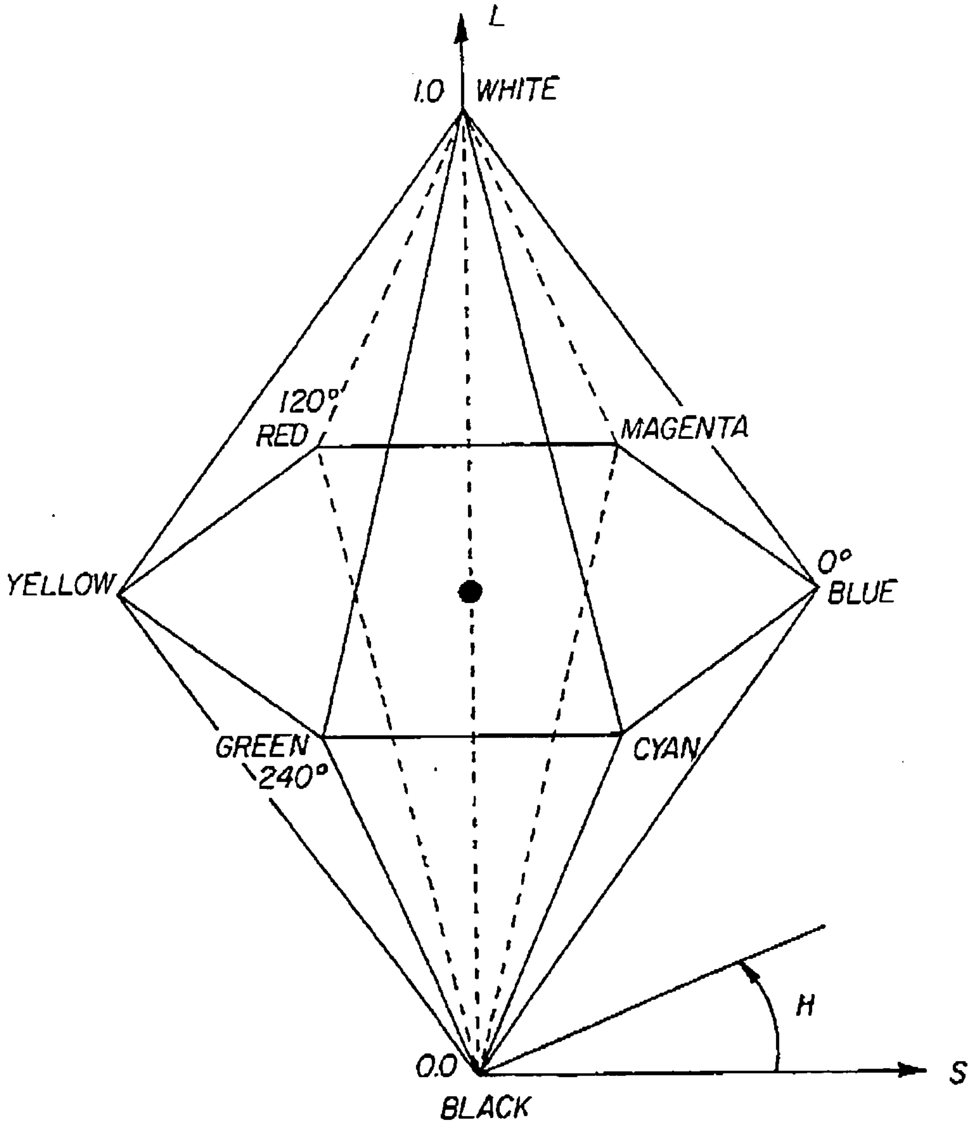

L
1.0
WHITE
120°
RED
MAGENTA
YELLOW
0°
BLUE
GREEN
240°
CYAN
H
0.0
BLACK
S

FIG. 5

FIG. 6a

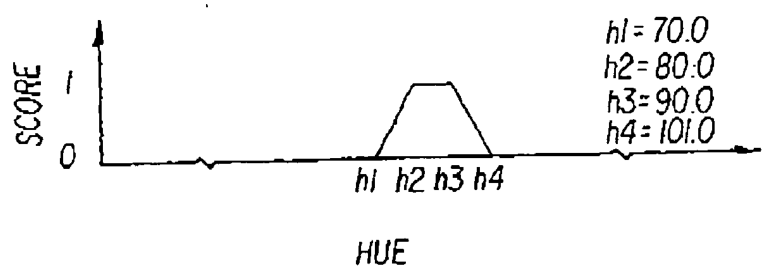


FIG. 6b

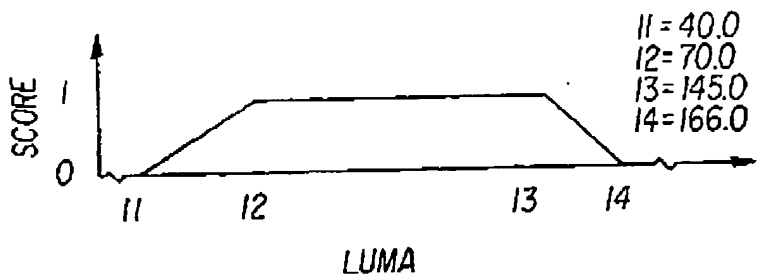
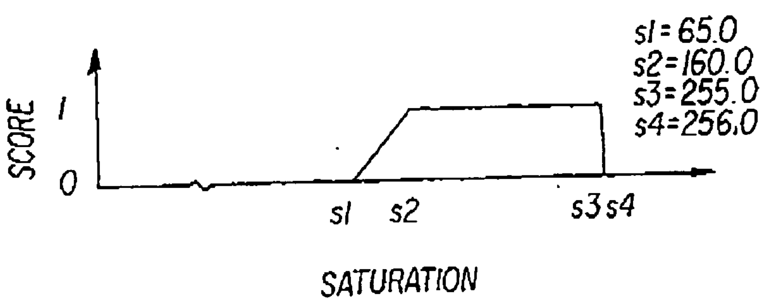


FIG. 6c



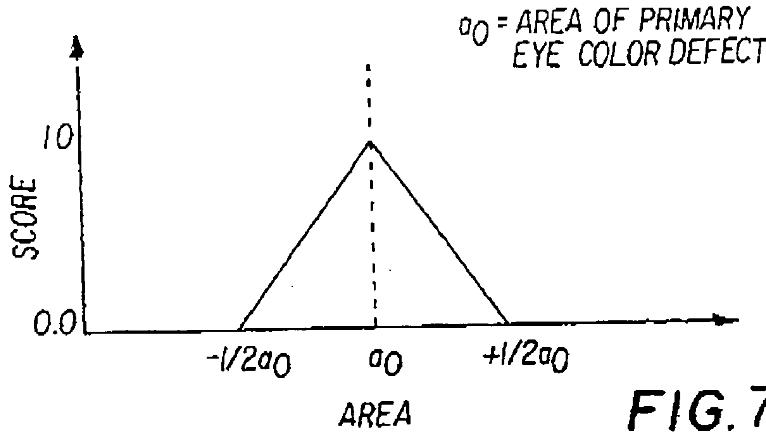


FIG. 7

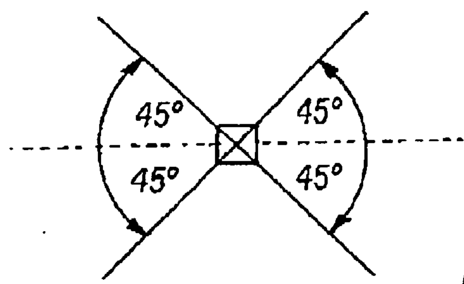
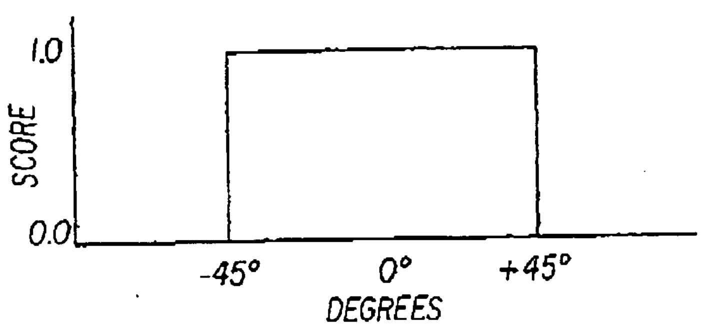


FIG. 8a



(ANGLE WITH RESPECT TO THE HORIZONTAL OF THE PRIMARY DEFECTIVE EYE)

FIG. 8b

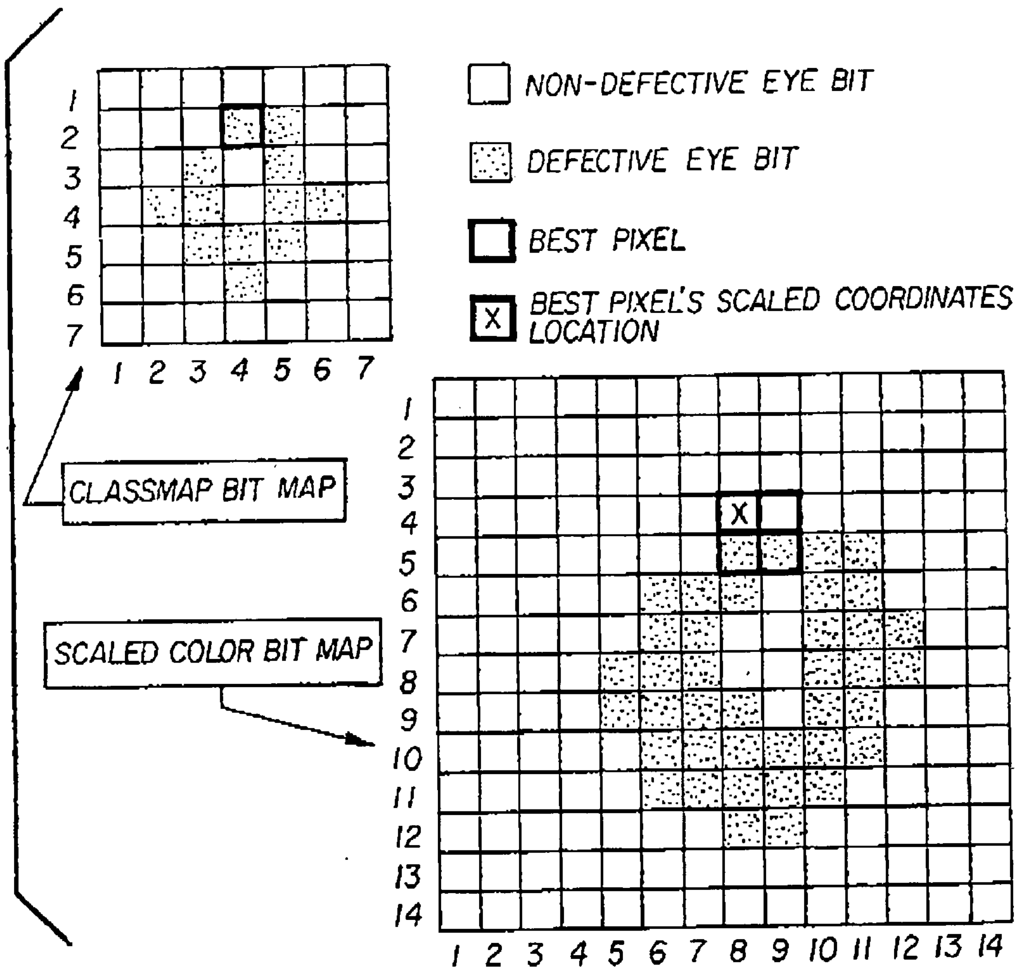
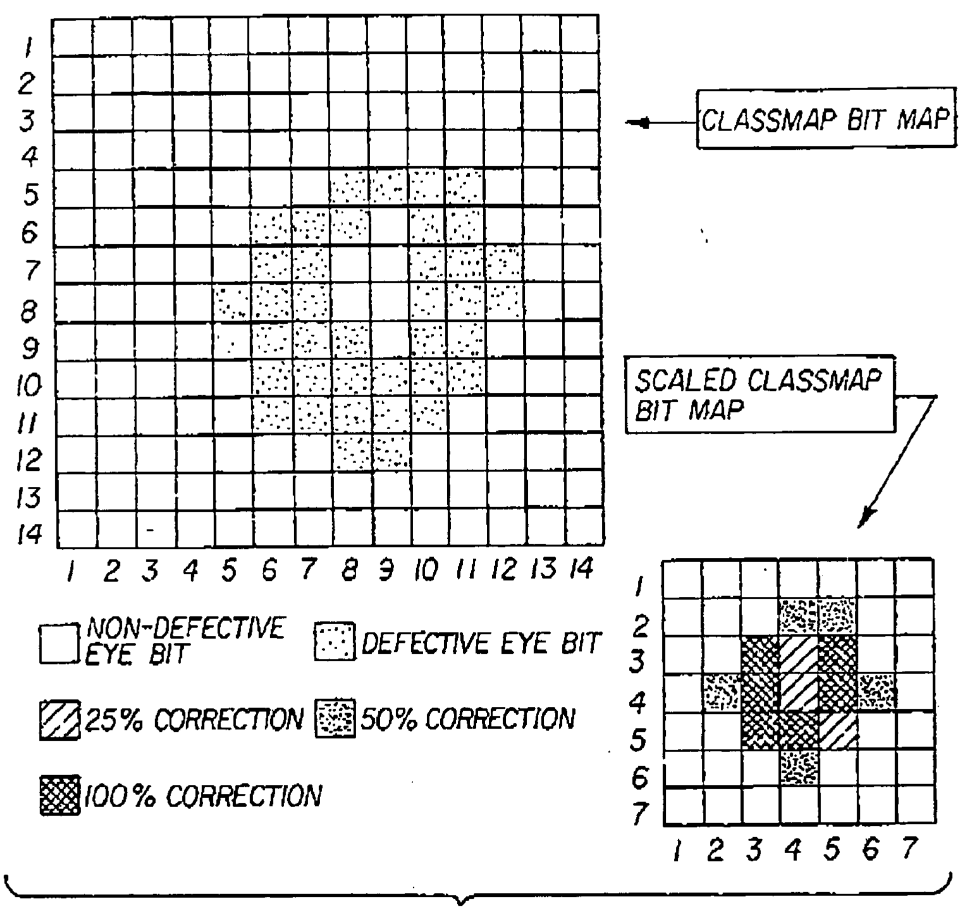
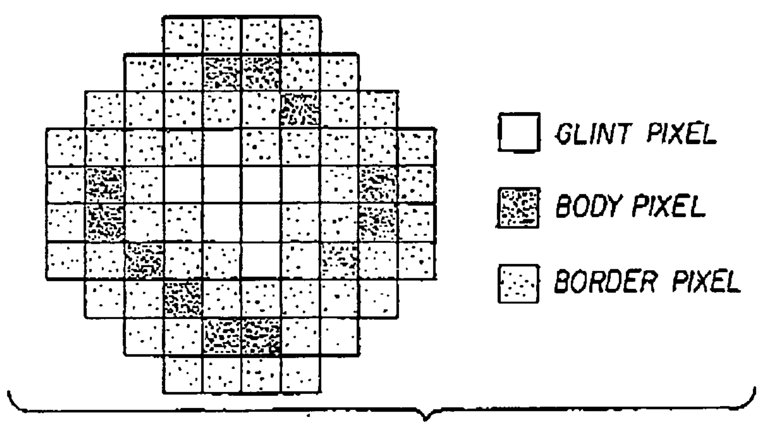

NON-DEFECTIVE EYE BIT
DEFECTIVE EYE BIT
BEST PIXEL
X BEST PIXEL'S SCALED COORDINATES LOCATION
CLASSMAP BIT MAP
SCALED COLOR BIT MAP
1 2 3 4 5 6 7
1 2 3 4 5 6 7 8 9 10 11 12 13 14

FIG. 9



1
2
3
4
5
6
7
8
9
10
11
12
13
14
1 2 3 4 5 6 7 8 9 10 11 12 13 14
CLASSMAP BIT MAP
SCALED CLASSMAP BIT MAP
1
2
3
4
5
6
7
1 2 3 4 5 6 7
NON-DEFECTIVE EYE BIT
DEFECTIVE EYE BIT
25% CORRECTION
50% CORRECTION
100% CORRECTION

FIG. 10



GLINT PIXEL
BODY PIXEL
BORDER PIXEL

FIG. 11